Bilateral Asymmetry in Paired Meristic Characters of Pacific Salmon

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ABSTRACT: The presence, extent, and direction of bilateral asymmetries of lateral line scales, gill rakers, branchiostegal rays, and pectoral fin rays of sockeye, chum, and pink salmon were examined. Some asymmetries were found in all characters in each species. Asymmetries, considering all species combined, occurred in approximately 72% of the lateral line scale comparisons, 59% of the gill raker comparisons, 70% of the branchiostegal ray comparisons, and 26% of the pectoral fin ray comparisons. Bilateral variation in these characters was not conclusively related to sex of the specimens; however, some tendency toward greater asymmetry in branchiostegals of females was shown. Complete evaluation of this tendency will require further examination.

Occurrences of asymmetries were evaluated in relation to the reliability of substituting counts from the opposite side when the chosen side was lost or severely damaged. Substitution of lateral line scales of sockeye salmon appeared to be feasible, but in chum salmon the right side counts were significantly greater. (Scale counts from pink salmon were not available, because of the extreme difficulty in obtaining reliable counts of the characteristically small scales.) Gill raker counts from sockeye salmon were found not to be interchangeable, as the right side counts significantly exceeded those of the left. In pink and chum salmon, bilateral variations in gill rakers appeared to be equal. Branchiostegal counts from the left sides of all species were significantly greater than those of the right. It was indicated that, for all species, pectoral fin ray counts from either side could be substituted reliably.

BILATERAL ASYMMETRY in various body parts has been recognized in many animals that have a bilaterally symmetrical form of development. The extent and cause of many asymmetries have not been defined. Asymmetries of fish in the order Pleuronectiformes (flatfish) result in normally dextral or sinistral individuals and have been attributed generally to the processes of natural selection and adaptions of the organism to life on the ocean bottom. Hubbs and Hubbs (1944:303), emphasizing the morphology of flatfish, have pointed out that some asymmetries appear in many body parts of all fishes, both externally and internally. In studies on meristic and other characters of four species of chars, Vladykov (1954:910) has noted somewhat higher gill raker counts on the right sides. In Pacific salmon bilateral asymmetry of branchiostegals, in which the left side overlaps the right anteriorly and contains more rays, has been described by Jordan and Evermann (1896:479).

As a consequence of these known asymmetries in fish, morphological characters from both sides of all species, ideally, should be examined for taxonomic and racial studies, or examination should be limited to one chosen side. If the latter alternative has been adopted, problems arise if the chosen side is mutilated or otherwise unobtainable. In racial studies on Pacific salmon (Fukuhara et al., 1962), data on various meristic characters were arbitrarily collected from the left side of all specimens. The racial study involved multivariate analysis of data from several meristic characters; therefore occasional failures to obtain information from any one lost or damaged character prevented the specimen's

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use and reduced the usable sample size. As the reliabiilty of the analysis was in part determined by the sizes of samples, unusable specimens were both a statistical and an economic loss.

Whether asymmetrical development, as shown in the branchiostegals of Pacific salmon, extends in some degree to other paired structures is unknown. With knowledge of the presence and extent of asymmetries in the characters considered, the opposite member of a lost character in fish specimens many times could be reliably substituted; if it were known that such characters essentially developed symmetrically, substitution would not contribute to the observed variability.

This paper presents an analysis of differences between the numbers of elements in left and right side structures of four paired meristic characters of sockeye (*Oncorhynchus nerka*), chum (*O. keta*) and pink (*O. gorbuscha*) salmon. In conjunction with this study, the reliability of the criteria utilized in obtaining the morphological characters will be discussed. The objectives of the analysis were to determine: (1) if bilateral asymmetry occurs in these characters; (2) the extent of asymmetries; (3) the direction of the asymmetrical development, as shown by one side tending to have a larger number of elements; and (4) the usefulness of the information in taxonomic and racial studies of the three species.

SAMPLES

Paired meristic characters were randomly obtained from specimens collected during the years 1956–1959 in the North Pacific Ocean, the Bering Sea, and from several North American and Kamchatkan rivers for racial studies conducted at the Seattle Biological Laboratory, Bureau of Commercial Fisheries. The characters examined included: (1) lateral line scales, (2) total gill rakers, (3) branchiostegal rays, and (4) pectoral fin rays. Lateral line scales of pink salmon were not examined because of extreme difficulty in obtaining reliable counts of the characteristically very small scales.

COLLECTION OF CHARACTERS

The paired bony structures were dissected from the specimens and left and right sides were radiographed separately. When the radiographs did not provide adequate resolution, the structure was stained and cleared, and the elements were counted manually. The data were obtained using criteria developed by Fukuhara et al. (1962: 27–28) for enumeration of characters. The definitions of criteria, elaborated upon below, include discussion of some structural characteristics and aberrancies which must be taken into account during enumeration of the characters. Application of these criteria minimized differences between individual interpretations and the time required for enumeration of the characters. As measured by periodic tests of between-reader variability, disagreements on independently obtained counts from radiographs averaged less than 3% for the bony characters. All scale counts were obtained by one biologist. Within-counter variability averaged less than 2%.

Lateral Line Scales

This character consisted of scales or scale pockets distinguishable by a tube which penetrates the scale and extends into the underlying lateral line canal. The count included the first scale posterior to the pectoral girdle and succeeding scales terminating at a position on the lateral line corresponding to the posterior margin of the hypural plate. This margin was determined by an incision made in the crease that resulted from upward flexion of the caudal fin. A severed scale or pocket was counted if more than half lay anterior to the incision. In immature specimens, acute scale imbrication required scale removal for accurate enumeration. Occasional irregularity of typically diagonal scale rows was caused by a supernumerary scale lying on the lateral line between two scales in the proper rows (Fig. 1). Some of these small scales lacked a tube and therefore were not counted.

Total Gill Rakers

This character consisted of rakers on the dorsal and ventral arms of the first branchial arch, including the most anterior rakers, which were

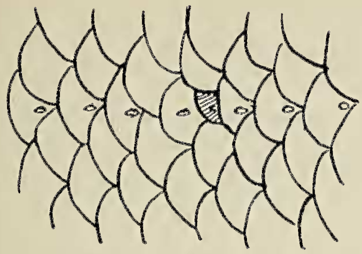


FIG. 1. Supernumerary scale lying on lateral line. Occasionally such scales are not penetrated by a lateral line canal tube.

frequently rudimentary. Rudimentary rakers occurring between the typically uniformly spaced rakers (Fig. 2*a*) and those lying outside the main row were not enumerated. Bifurcated or branched rakers (Fig. 2*b*) with a common base were counted as one raker.

Branchiostegal Rays

All bony elements of the branchiostegal were included in counts of this character. In chum salmon, particularly, the reduced size and modified shape of some anterior rays (Fig. 3) resulted in very deceptive radiographic presentations. In preparation for radiographing, the skin and cartilaginous material anterior to these rays had to be carefully removed to minimize deception. Careful examination was also required for recognition of an occasional ray which appeared as two rays due to the presence of a prominent lengthwise suture. Dissection and staining were used to resolve doubtful conditions.

Pectoral Fin Rays

All fin rays which extended to the basal bones of the fin were included in the character. So-called "floating rays," which occurred in various positions among the normal rays, were not counted (Fig. 4*a*). No counts were taken from fins in which a lateral process arising from one position had fused with a process on the opposite side arising either anterior or posterior to it. This left both a right and a left side process standing alone, as shown in Figure 4*b*.

STATISTICAL PROCEDURES

For each character, the right side counts were subtracted from the left side, differences being positive when the left side counts exceeded the right and negative when the right side counts exceeded the left. The significance of the mean difference between the number of meristic elements in left and right side structures observed in each sample was determined using the Student's t-distribution:

$$t = (X - \mu)/Sx$$

where X equals the mean difference of left side counts minus those from the right side, μ equals zero, and Sx is the standard error of the sample mean difference. The hypothesis tested was that the difference between left and right side counts was zero. The hypothesis was rejected at the 0.05 level. The probability levels of the observed t-values are presented in the tables of data and results.

The extent of over-all asymmetry in each character was measured by the percentage $100(L + R)/N$, and the direction of asymmetry by the percentage of sinistrality $100L/(L + R)$, where L equaled the number of specimens with greater left side counts, R equaled the number with greater right side counts, and N equaled the total sample size, including specimens with equal numbers of elements in the left and right side structures.

Although there was little or no known biological reason to suspect that differential asymmetrical development was related to sex or area of origin of salmon, these possibilities were explored, in so far as the data warranted, for any obvious tendencies of this nature. Actual statis-

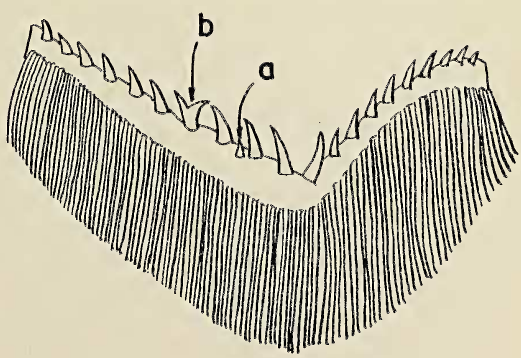


FIG. 2. First left gill arch. *a,* Small raker between regularly spaced rakers on ventral arm of the arch; *b,* a bifurcated raker on the ventral arm.

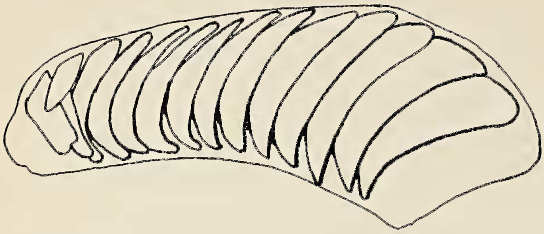


FIG. 3. Chum salmon branchiostegal, showing modified configuration of anterior rays.

tical analyses of between-sex, within-sample, differences were not attempted due to small sample sizes; nor were between-area differences tested for statistical significance, inasmuch as many samples were obtained from the high seas and contained specimens of unknown and perhaps differing origins.

For each sample, probability values associated with the t-distribution for differences between paired counts were obtained by sex. Sexes were then combined and analysed as a single sample. Similarly, for each species, probability values were determined for all males and females separately; the sexes were then combined to determine the mean differences between left and right side structures for comparison among species.

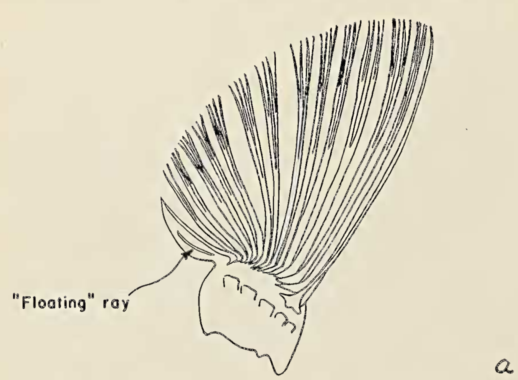
RESULTS

The results of the analyses of observed differences between left and right side structures are discussed for each meristic character. The occurrence, direction, and significance of the mean differences between left and right side counts have been examined by species, sample location, and sex.

Bilateral Variation in Lateral Line Scales

In sockeye salmon (Table 1), the percentages of specimens exhibiting asymmetry in lateral line scales and the direction of asymmetry varied among samples of each sex and among combined samples of both sexes from different locations. As shown by the right-hand column (headed 100 P), the probability values for the observed mean differences were not significant. For the combined samples, males with differences in left and right side counts averaged 69%, and females averaged 65%. Asymmetry between left and right side scale counts occurred in approximately 67% of the total of 395 specimens. The direction of asymmetry indicated that the right side developed approximately 0.12 scales more than the left side. This difference could have occurred by chance alone more than 5 out of 100 times (P greater than 5); thus, the left and right side variations in lateral line scale counts were not significantly different in sockeye salmon.

Examination of data from chum salmon scale counts (Table 1), by sample location and sex, indicated some disparity among samples within these categories. Mean differences between left and right side counts of males were significant in one sample from the high seas. In this sample, collected by the MV "Paragon," the mean difference for females was not significant. In the Hokkaido Island sample both males and females



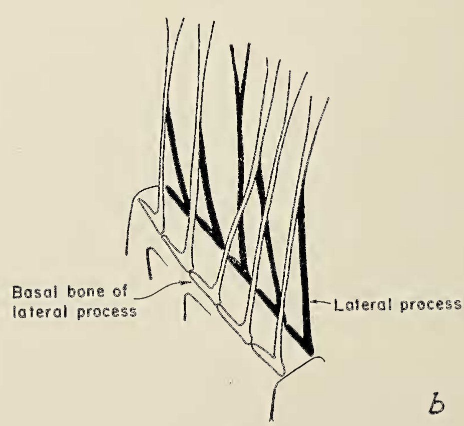


FIG. 4. Schematic presentations of aberrancies occurring in pectoral fins. *a,* "Floating" ray; *b,* fusion of lateral processes from adjacent fin ray bases.

TABLE 1

BILATERAL VARIATION IN THE NUMBER OF LATERAL LINE SCALES

SAMPLE SOURCE (YEAR)	SPECIES	SEX	NUMBER EXAMINED	% ASYMMETRICAL	% ASYMMETRICAL TOWARD LEFT	MEAN OF (L–R)	100 (P)
MV "Attu" 56°N, 173°W (1957)	sockeye	male	13	69.2	66.7	0.307	>50
		female	38	65.8	56.0	0.053	>50
		total	51	66.6	58.8	0.118	>50
53°N, 165°W (1957)	sockeye	male	32	68.8	50.0	–0.031	>50
		female	19	63.2	33.3	–0.579	>50
		total	51	66.6	42.8	–0.235	>50
50°N, 170° W (1957)	sockeye	male	11	72.7	37.5	0	—
		female	24	62.5	66.5	0.208	>40
		total	35	65.7	56.5	0.142	>50
Okanogan River (1957)	sockeye	male	11	90.9	50.0	0	—
		female	13	76.9	50.0	0.154	>50
		total	24	83.3	50.0	0.083	>50
Japanese Fishery 50°N, 168°E (1958)	sockeye	male	61	59.0	41.6	–0.197	>10
		female	54	68.5	43.2	–0.241	>10
		total	115	63.4	42.4	–0.217	> 5
51°N, 172°E (1958)	sockeye	male	49	75.6	44.1	–0.244	>10
		female	74	62.2	43.4	–0.175	>10
		total	119	67.2	43.7	–0.202	>10
Combined sockeye samples		male	173	68.8	46.2	–0.116	>10
		female	222	65.3	47.6	–0.126	>10
		total	395	66.8	47.0	–0.122	> 5
MV "Pioneer" 50°–53°N, 175°–180°W (1957)	chum	male	41	75.6	41.9	–0.341	>10
		female	33	72.7	20.8	–1.121	< 1
		total	74	74.3	32.7	–0.689	< 1
MV "Paragon" 50°–60°N, 175°W (1957)	chum	male	72	76.3	36.3	–0.430	< 5
		female	63	84.1	52.8	0.111	>50
		total	135	80.0	44.4	–0.178	>10
Hokkaido I. (1958)	chum	male	109	70.6	25.9	–0.670	< 1
		female	51	72.5	35.1	–0.608	< 2
		total	160	71.2	28.9	–0.650	< 1
Combined chum samples		male	222	73.4	32.5	–0.532	< 1
		female	147	77.6	40.4	–0.415	< 2
		total	369	75.1	35.7	–0.485	< 1

showed significant differences in counts from opposite sides. Approximately 78% of the total female chum salmon samples exhibited asymmetrical development, while only 73% of the males were asymmetrical. However, the probability levels for the mean differences between sides for both males and females were not significant. Scale counts from the combined total of 369 chum salmon indicated some asymmetrical development in 75% of the specimens. Of all the specimens with asymmetries, counts from the right sides exceeded the left in approximately 64%. The over-all mean difference between left and right side counts (–0.485) was significant at the 0.01 level.

Bilateral Variation in Gill Rakers

Gill raker counts from the first left and right branchial arches were collected from sockeye salmon taken at 10 locations (Table 2). Male and female groups varied similarly, with no significant values occurring in either category in the individual samples. Probability values for sexes combined were significant in samples from 3 locations. Bilateral asymmetry occurred in approximately 63% of the total of 668 sock-

TABLE 2

BILATERAL VARIATION IN THE NUMBER OF GILL RAKERS

SAMPLE SOURCE (YEAR)	SPECIES	SEX	NUMBER EXAMINED	% ASYMMETRICAL	% ASYMMETRICAL TOWARD LEFT	MEAN OF (L–R)	100 (P)
Nichiro	sockeye	male	70	58.6	58.5	.228	>10
50°–53°N,		female	93	63.4	59.3	.172	>10
160°–178°E (1956)		total	163	61.3	59.0	.196	< 5
Karluk River	sockeye	male	35	68.6	66.6	.343	> 5
(1957)		female	15	46.7	71.4	.200	>40
		total	50	62.0	67.7	.300	> 5
Naknek River	sockeye	male	12	66.7	75.0	.500	>10
(1957)		female	12	66.7	75.0	.583	> 5
		total	24	66.7	75.0	.542	< 5
Egegik River	sockeye	male	18	55.6	40.0	–.056	>50
(1957)		female	23	65.2	60.0	.130	>40
		total	41	60.9	52.0	.049	>50
Kvichak River	sockeye	male	12	75.0	66.6	.250	>20
(1957)		female	18	50.0	66.6	.278	>20
		total	30	60.0	66.6	.268	>10
MV "Tordenskjold"	sockeye	male	31	67.7	47.6	–.194	>10
51°N, 170°W		female	41	70.7	44.8	–.146	>10
(1959)		total	72	69.4	46.0	–.167	>10
52°N, 172°W	sockeye	male	17	88.2	66.7	.530	>10
(1959)		female	10	60.0	33.3	–.200	>50
		total	27	77.8	57.1	.259	>10
56°N, 170° W	sockeye	male	51	66.7	50.0	–.059	>40
(1959)		female	42	66.7	64.3	.333	>10
		total	93	66.7	56.4	.118	>10
51°N, 180°W	sockeye	male	22	59.1	61.5	.454	>10
(1959)		female	15	46.7	85.7	.533	> 5
		total	37	54.1	70.0	.486	< 5
USSR: Ozernaya River	sockeye	male	46	56.5	57.7	.174	>10
(1959)		female	85	60.0	51.0	0	—
		total	131	58.8	53.2	.061	>50
Combined sockeye		male	314	64.0	57.7	.172	< 1
samples		female	354	61.9	57.5	.136	< 5
		total	668	62.9	57.6	.153	< 1
MV "Celtic"	chum	male	41	46.3	21.1	–.366	< 1
50°–57°N,		female	29	62.1	44.4	–.172	>10
145°–154°W (1956)		total	70	52.8	32.4	–.286	< 1
Ketchikan	chum	male	11	27.3	33.3	–.090	>50
(1959)		female	9	77.8	71.4	.333	>10
		total	20	33.0	60.0	.100	>50
USSR: Ozernaya River	chum	male	63	61.9	43.6	–.111	>40
(1959)		female	39	51.3	45.0	–.027	>50
		total	102	57.8	44.1	–.078	>40
Bolshaya River	chum	male	22	63.6	50.0	.045	>50
(1959)		female	67	58.2	51.3	.015	>50
		total	89	59.6	50.9	.022	>50
Okhotsk River	chum	male	29	44.8	61.5	0	—
(1959)		female	42	47.6	40.0	–.119	>30
		total	71	46.5	48.5	–.070	>30

TABLE 2 (continued)

Combined chum samples		male	166	53.0	42.0	–.138	> 5
		female	186	55.9	48.1	–.038	>50
		total	352	54.5	45.3	–.085	> 5
Petersburg (1959)	pink	male	37	54.0	60.0	.027	>50
		female	18	72.2	61.5	.111	>50
		total	55	60.0	66.6	.054	>50
Fraser River (1959)	pink	male	31	64.5	60.0	.064	>50
		female	18	50.0	55.6	.056	>50
		total	49	59.2	58.6	.061	>50
Combined pink samples		male	68	58.8	60.0	.044	>50
		female	36	61.1	59.1	.083	>50
		total	104	59.6	59.7	.058	>50

eye salmon examined. Of specimens exhibiting asymmetry, 58% had larger left side counts. In the combined data for the species, left side counts exceed the right by 0.15 rakers, which was significant at the 0.01 level.

In chum salmon (Table 2), the mean differences between left and right side gill raker counts were significant for only one sample collected on the high seas in 1956. Mean differences and probability levels varied among the samples of both males and females, with no apparent evidence of sexual dimorphism. The probability level for the mean differences calculated for all males combined was greater than 5%, and for all females was greater than 50%. Of the total of 352 pairs of chum salmon gill raker counts, 54% showed asymmetrical development of the structures. Asymmetry was toward the right side, which averaged 0.085 more rakers in these specimens; however, this difference was not significant.

In pink salmon (Table 2), differences between left and right side gill raker counts varied little among the categories of sample location or sex. In this species, 59% of the males and 61% of the females examined showed some asymmetry in gill raker counts from opposite sides of the fish, with a slight but consistent tendency for the left side to exceed the right. The probability levels for the samples and for all specimens combined, however, indicated that the observed mean differences were not statistically significant.

Bilateral Variations in Branchiostegal Rays

Pairs of branchiostegal ray counts were collected from 407 sockeye, 350 chum, and 59 pink salmon (Table 3). Although very few specimens of pink salmon were examined, in this species, as well as in the other two, the females exhibited a greater percentage of asymmetrical development, with larger mean differences than the males. Only in sockeye samples from the Karluk and Egegik rivers, and in one chum salmon sample taken by the MV "Celtic," was the trend reversed. The mean differences observed were significant for all individual samples and also for each sample of male or female fish. In the combined data for each of the three species, asymmetrical development occurred in 62%, 77%, and 71% of the sockeye, chum, and pink salmon, respectively. Left side counts exceeded right side counts in 93% of the asymmetrical pairs of sockeye salmon branchiostegals, in 96% of the chums, and in 98% of the pink salmon. In sockeye salmon, the number of branchiostegal rays in the left side structures exceeded the right by approximately 0.6 rays; in chum and pink salmon the mean differences averaged 0.8 rays. The mean differences in all three species were statistically significant.

Bilateral Variation in Pectoral Fin Rays

Comparisons were made of fin ray counts from left and right pectoral fins of 407 sockeye, 357 chum, and 97 pink salmon (Table 4). No consistent trends were observed toward sexual dimorphism or effect of sampling location in respect to asymmetry of this character. For the combined data for each species, asymmetry occurred in only 14–24% of the specimens—much less frequently than for the other three characters examined. Variations in the number of rays from opposite sides resulted in very

TABLE 3

BILATERAL VARIATION IN THE NUMBER OF BRANCHIOSTEGAL RAYS

SAMPLE SOURCE (YEAR)	SPECIES	SEX	NUMBER EXAMINED	% ASYMMETRICAL	% ASYMMETRICAL TOWARD LEFT	MEAN OF (L–R)	100 (P)
Nichiro	sockeye	male	41	61.0	80.0	.415	< 1
50°–53°N,		female	72	54.2	87.0	.472	< 1
160°–178°E (1956)		total	113	56.6	84.0	.451	< 1
Karluk River	sockeye	male	35	60.0	90.0	.543	< 1
(1957)		female	15	46.7	100.0	.533	< 1
		total	50	56.0	89.0	.540	< 1
Naknek River	sockeye	male	14	64.3	100.0	.857	< 1
(1957)		female	18	77.8	100.0	.889	< 1
		total	32	71.9	100.0	.875	< 1
Egegik River	sockeye	male	22	81.8	94.0	.818	< 1
(1957)		female	24	70.8	100.0	.750	< 1
		total	46	76.1	97.0	.783	< 1
Kvichak River	sockeye	male	13	38.5	100.0	.385	< 5
(1957)		female	16	87.5	100.0	.938	< 1
		total	29	65.5	100.0	.690	< 1
Ozernaya River	sockeye	male	46	52.2	95.8	.522	< 1
(1959)		female	91	65.9	95.0	.659	< 1
		total	137	61.3	95.2	.613	< 1
Combined sockeye		male	171	59.6	91.2	.556	< 1
samples		female	236	64.0	94.7	.640	< 1
		total	407	62.2	93.3	.604	< 1
MV "Celtic"	chum	male	39	76.9	73.6	.820	< 1
50°–57°N,		female	31	80.6	96.0	.774	< 1
145°–154° W (1956)		total	70	78.6	94.5	.800	< 1
Ketchikan	chum	male	13	76.9	100.0	.923	< 1
(1959)		female	9	77.8	100.0	1.333	< 1
		total	22	77.2	100.0	1.090	< 1
Ozernaya River	chum	male	58	75.9	90.9	.655	< 1
(1959)		female	39	92.3	100.0	.974	< 1
		total	97	82.5	95.0	.784	< 1
Bolshaya River	chum	male	24	70.8	88.2	.625	< 1
(1959)		female	67	77.6	100.0	.900	< 1
		total	91	75.8	97.1	.824	< 1
Okhotsk River	chum	male	29	62.1	94.4	.552	< 1
(1959)		female	41	73.2	100.0	.854	< 1
		total	70	68.6	97.9	.728	< 1
Combined chum		male	163	73.0	92.4	.693	< 1
samples		female	187	80.2	99.3	.904	< 1
		total	350	76.8	96.3	.806	< 1
Ketchikan	pink	male	31	67.7	95.2	.677	< 1
(1959)		female	28	75.0	100.0	.893	< 1
		total	59	71.2	97.6	.780	< 1

TABLE 4

BILATERAL VARIATION IN THE NUMBER OF PECTORAL FIN RAYS

SAMPLE SOURCE (YEAR)	SPECIES	SEX	NUMBER EXAMINED	% ASYMMETRICAL	% ASYMMETRICAL TOWARD LEFT	MEAN OF (L–R)	100 (P)
Nichiro 50°–53°N, 160°–178°E (1956)	sockeye	male	40	25.0	60.0	.075	>40
		female	69	21.7	53.3	.014	>50
		total	109	22.9	56.0	.037	>40
Karluk River (1957)	sockeye	male	36	19.4	57.1	.028	>50
		female	16	31.2	40.0	–.062	>50
		total	52	23.0	50.0	0	—
Naknek River (1957)	sockeye	male	14	42.8	16.6	–.286	>10
		female	17	29.4	60.0	.059	>50
		total	31	35.4	36.3	–.097	>20
Egegik River (1957)	sockeye	male	22	22.7	40.0	–.045	>50
		female	23	13.0	66.7	.043	>50
		total	45	17.7	50.0	0	—
Kvichak River (1957)	sockeye	male	13	15.3	50.0	0	—
		female	18	16.6	33.3	–.056	>50
		total	31	16.1	40.0	–.032	>50
Ozernaya River (1959)	sockeye	male	47	17.0	75.0	.085	>10
		female	92	22.8	57.1	.022	>30
		total	139	20.9	62.1	.058	>20
Combined sockeye samples		male	172	22.1	52.6	.017	>50
		female	235	22.1	53.8	.021	>40
		total	407	22.1	53.3	.019	>40
MV "Celtic" 50°–57°N, 145°–154°W (1956)	chum	male	41	31.7	46.1	–.024	>50
		female	31	29.0	44.4	–.032	>50
		total	72	30.5	45.4	–.027	>50
Ketchikan (1959)	chum	male	13	23.0	66.7	.076	>50
		female	10	40.0	75.0	.200	>10
		total	23	30.4	71.4	.130	>10
Ozernaya River (1959)	chum	male	62	19.4	41.6	–.032	>50
		female	38	15.8	83.3	.105	>10
		total	100	18.0	55.6	.020	>50
Bolshaya River (1959)	chum	male	23	13.0	66.7	.043	>50
		female	68	23.5	75.0	.118	>20
		total	91	20.9	73.7	.099	>20
Okhotsk River (1959)	chum	male	29	10.3	66.7	.034	>50
		female	42	16.7	57.1	.024	>40
		total	71	14.1	60.0	.028	>50
Combined chum samples		male	168	23.8	50.0	–.006	>50
		female	189	22.2	66.7	.074	>50
		total	357	21.3	59.2	.036	>50
Ketchikan (1959)	pink	male	38	13.2	60.0	.026	>50
		female	12	16.7	100.0	.166	>20
		total	50	14.0	71.4	.060	>20
Prince William Sound (1959)	pink	male	40	15.0	66.7	.050	>50
		female	7	42.8	00.0	–.428	>10
		total	47	19.1	44.4	–.021	>50
Combined pink samples		male	78	14.1	63.6	.042	>10
		female	19	26.3	40.0	–.053	>50
		total	97	16.5	56.2	.021	>50

small mean differences for all three species; the mean differences for sockeye and pink salmon were approximately 0.02 and for chums 0.04. Although the left pectoral fin counts generally exceeded the right, the tests for differences were not statistically significant for any sample or species.

CONCLUSIONS

The results of this study show that sockeye, chum, and pink salmon, which are essentially bilaterally symmetrical animals, exhibit some asymmetries with respect to all four paired meristic characters considered. From the specimens examined no conclusive relationship was shown between the occurrences of asymmetries and the sex or the area from which samples were obtained; however, these possible sources of variation were not rigidly tested, for reasons given earlier in the text.

In taxonomic and racial studies involving lateral line scale counts, interchanging counts from left and right sides of chum salmon introduces an additional source of variation and, in a situation of considerable numbers of substitutions, may be a serious source of bias. In sockeye salmon, substitution of one side for another appears feasible; however, variation in the probability levels of individual samples suggests that, for more complete assurance of reliability, examination of a larger number of sockeye salmon specimens would be desirable.

Substitution of gill raker counts from sockeye salmon is not advisable. In chum salmon the observed differences in left and right side counts are not statistically significant; however, the differences observed in one high seas sample containing 70 specimens raise some doubt in situations in which loss of a character, resulting in reduced sample size, is a lesser problem than maintaining minimum variations in the data to be collected. Gill raker counts from opposite sides of pink salmon vary equally, and substitution of the opposing structure will not seriously affect the analysis.

In the species considered, branchiostegal counts from left and right sides can not be reliably interchanged. Also, the extent of the asymmetry observed in this character is of a greater magnitude in female salmon. Further study of sexual differences in left and right side variations is required, however, to yield conclusive evidence of the existence of sexual dimorphism in respect to bilateral variations in branchiostegals of Pacific salmon.

Pectoral fin rays from the left and right side structures are essentially equal in number in all three species. Substitution of sides in obtaining counts of pectoral fin rays would contribute little variation to mean counts of this character.

REFERENCES

FUKUHARA, FRANCIS M., SUETO MURAI, JOHN J. LALANNE, and ARPORNA SRIBHIBHADH. 1962. Continental origin of red salmon as determined from morphological characters. Intern. North Pacific Fisheries Comm., Vancouver, B. C., Bull. 8:15–109.

HUBBS, CARL L., and LAURA C. HUBBS. 1944. Bilateral asymmetry and bilateral variations in fishes. Pap. Mich. Acad. Sci., Arts, and Letters 30:229–310, 1 pl.

JORDAN, DAVID STARR, and BARTON W. EVERMANN. 1896. The Fishes of North and Middle America. U. S. Nat. Mus. Bull. 47, Part 1. 1240 pp.

VLADYKOV, V. D. 1954. Taxonomic characters of the eastern North American chars (*Salvelinus* and *Cristovomer*). J. Fisheries Res. Board, Canada 11(6):904–932.